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PROF. G. H. F. NUTTALL

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TREASURY DEPARTMENT.
U. S. Marine-Hospital Service.

REPORT

ON

Formaldehyd Disinfection

IN A

Vacuum Chamber.

BY

P. A. Surg. E. K. SPRAGUE, U. S. M. H. S.
(Acting Director Hygienic Laboratory.)

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FORMALDEHYD DISINFECTION IN A VACUUM CHAMBER,

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P. A. Surg. E. K. SPRAGUE, U. S. M. H. S.

(Acting Director Hygienic Laboratory.)

HYGIENIC LABORATORY, U. S. MARINE-HOSPITAL SERVICE,
Washington, D. C., September 18, 1899.

SIR: I have the honor to submit the following report of experiments conducted in the hygienic laboratory in disinfection with formaldehyd, combined with dry heat, in a vacuum chamber, to determine the quantity of formalin (40 per cent solution of formaldehyd gas) and degree of heat required for complete disinfection by this method in one hour or less:

Hitherto most of the experiments with formaldehyd have been made with a small percentage of the gas and with a long exposure, twelve to forty-eight hours. There can be no question regarding its efficiency when thus employed, but its field of usefulness would be greatly limited were the minimum time of exposure to be twelve hours. The fact that no apparatus had been constructed on a plan such that a high percentage of gas could be secured and maintained compelled the employment of relatively small quantities. With the Kinyoun-Francis formaldehyd disinfector, manufactured by the Kensington Engine Works, Philadelphia, it is possible to make use of as high a percentage as may be desired, and the chamber being air tight, the quantity of gas is not decreased during the time of exposure.

DESCRIPTION OF APPARATUS.

This apparatus is a jacketed steam disinfecting chamber (Fig. 1) with a capacity of 1,680 liters. To the cylinder is attached a vacuum apparatus, a formaldehyd generator, and an ammonia generator. The cylinder is also fitted with a rack in which the various articles for disinfection are placed. The formaldehyd and ammonia generators are attached at the middle of one side of the cylinder and, although distinct, are covered with a Russia iron jacket, which would conceal their identity were it not for the fact that to each is attached a brass plate, one marked "Formalin" and the other "Ammonia." The formaldehyd generator is a copper boiler, containing a copper coil, with a capacity of 3.21

liters. The ammonia generator is of the same construction and capacity, with the exception that the copper is replaced by iron. The coils are connected with a steam boiler, and the generators communicate with the disinfecting chamber by means of small pipes which are fitted with the proper stopcocks.

METHOD OF OPERATING.

Steam is turned into the jacket until a temperature of at least 80° C. is obtained within the chamber. The articles to be disinfected are placed in the rack or car which is rolled into the chamber, the door is closed and secured, and a vacuum of 15 to 20 inches obtained. By this time, steam having been allowed to course through the coil within the generator containing the formalin mixture, there should be a pressure of 40 to 60 pounds. The heat in the chamber has been gradually increased, and the thermometer should register nearly or quite 90° C. With the above pressure and temperature, the valve between the generator and chamber is opened just enough to permit the escape of gas in sufficient quantity to cause the pressure to gradually decrease.

At the end of ten or fifteen minutes all the gas has probably been expelled and the valve may now be closed. Steam is kept slowly coursing through the jacket in order to maintain a constant temperature of 90° C., or more. A higher degree of heat, while doing no harm, does not appear to increase the efficiency of the formaldehyd, but it is certainly diminished at a lower temperature. The vacuum will usually fall seven or eight pounds, and possibly more, according to the quantity of gas entering the chamber. At the end of one-half hour the vacuum may be broken and air allowed to fill the chamber. This mixture of air and formaldehyd is then exhausted, and the ammonia generator, previously supplied with aqua ammonia, one half as much as of formalin, is operated in the same manner as already described for formaldehyd; the latter having been in a great measure removed with the air, a small quantity of ammonia will neutralize the residue. Air is again allowed to enter the chamber and the door may now be opened. It is usually found that there is a slight excess of ammonia, but not enough to cause any annoyance. Neutralization of the formaldehyd occurs very promptly, consequently only the few minutes necessary for operating is consumed by this part of the process.

PREPARATION OF FORMALIN MIXTURE.

The formalin mixture used in these experiments was prepared as follows: Formalin, 100 parts; calcium chloride, 20 parts; glycerin, 10 parts.

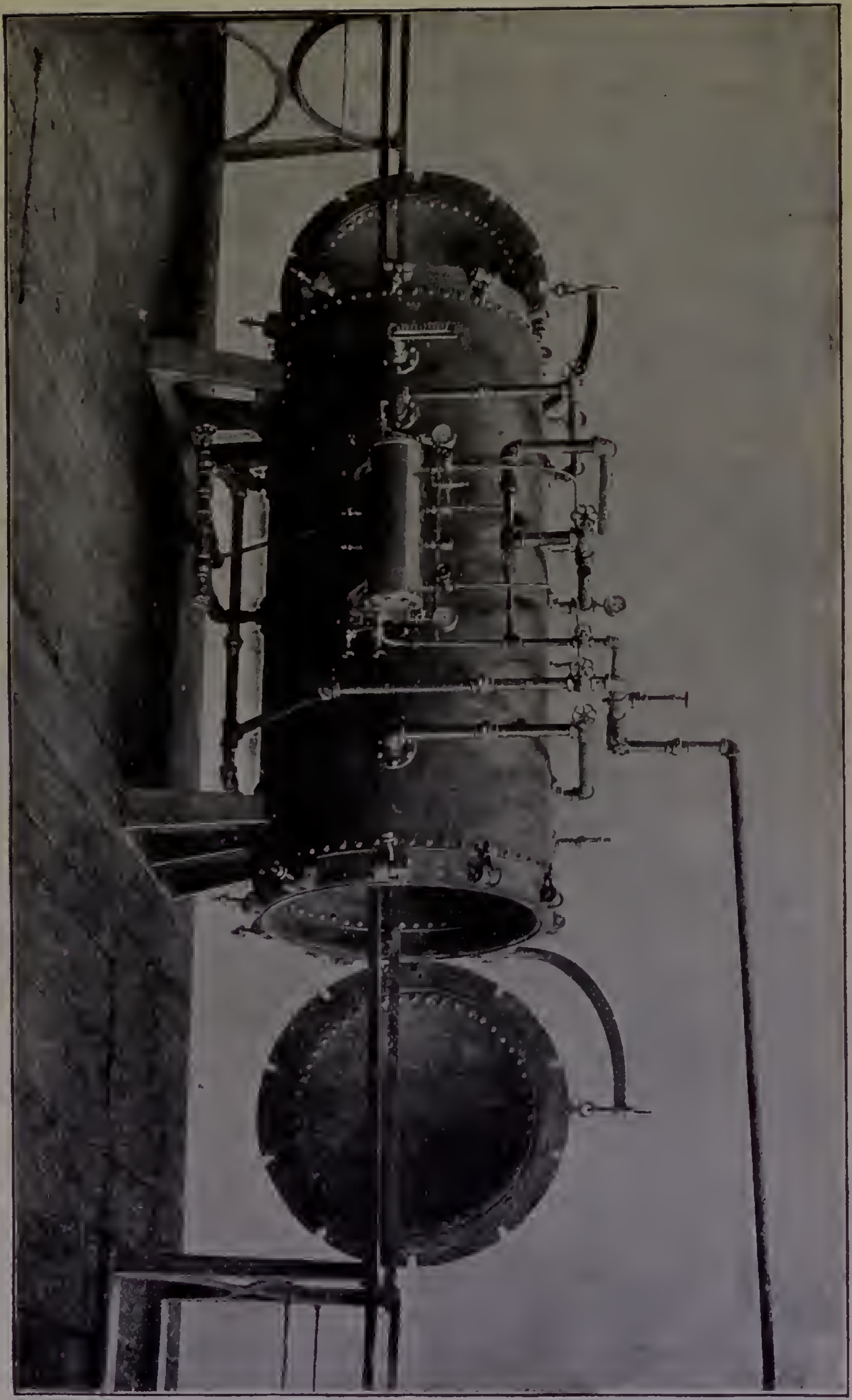

FIG. 1.

Commercial calcium chloride usually contains considerable water and before being weighed for the mixture was thoroughly dried by heat. It was then pulverized and mixed with the formalin. The glycerin was added last.

When the pressure in the generator had fallen to zero by the escape of all the formaldehyd, there remained a considerable quantity of a sirupy liquid resembling in odor and appearance light colored molasses. It was necessary to draw off this liquid residue after each experiment, otherwise it became thick and tarry, clogging the drainage pipe.

No estimation of the percentage of formaldehyd was made in these experiments because of the difficulty of accurately determining the quantity of gas in practical work. A definite quantity of the formalin mixture was taken for each series and, as will be explained later, the ratio existing between the amount of formalin and the capacity of the chamber may be used as a basis for calculating the quantity for a chamber of any size.

CULTURES.

The cultures employed were in each instance as nearly similar as it was possible to have them. The typhoid and diphtheria were forty-eight hours old bouillon cultures, and the anthrax was of several days growth—old enough so that spores were always present.

Small slips of sterile crash were moistened with the culture, and those to be used in the dry state were allowed to remain in a Petri dish, with the cover slightly raised, at room temperature until the moisture evaporated; those to be used wet were freshly prepared and no time given for evaporation. Each slip was then wrapped in sterile cheese cloth so that it was protected by about ten thicknesses. While the cultures were exposed under a variety of conditions, they were always prepared in the same manner. At the conclusion of each experiment they were removed, the crash slips were placed in sterile bouillon tubes and incubated at 37° C. for seven to twelve days.

It was found that while the controls always grew in twenty-four to forty-eight hours, the growth in many instances in the other tubes seemed to be inhibited so that development did not occur until the sixth or eighth day. In all the experiments with anthrax alone the tubes were incubated ten to twelve days. This particular organism was very virulent, and in cases of doubt as to the growth, mice were inoculated to decide the question.

In an unpublished series of experiments conducted at the national quarantine station, Angel Island, San Francisco, by Passed Assistant Surgeon Rosenau, he reached the conclusion that by combining dry heat and formaldehyd he obtained better results than with the gas at ordinary temperatures. The degree of heat and the quantity of formalin required for efficient work in a given space were not determined.

In order to decide these points and to complete the work begun two years ago, those experiments were undertaken. It was deemed advisable, first, to determine accurately the effect of dry heat alone upon the organisms selected, which was in reality a question of penetration, because the lowest temperature in any series, 80° C., would kill diphtheria and typhoid in less than one hour; second, to ascertain the germicidal effect of formaldehyd in large quantity at ordinary temperature, 25°–30° C.; and, third, to decide upon the most efficient combination of heat and formaldehyd. All experiments were carefully controlled by 1 to 3 tubes for each germ.

SERIES I.

Temperature 80° C.; time, one hour; no vacuum.

A. *Dried cultures.*

1. Cultures free in chamber:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	growth.

2. Cultures buried in hair pillows:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	growth.

3. Cultures buried in feather pillows:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	growth.

4. Cultures inside tightly rolled blanket:

Typhoid, dried	no growth.
Diphtheria, dried	growth.
Anthrax, dried	growth.

5. Cultures buried in cotton mattress:

Typhoid, dried	no growth.
Diphtheria, dried	growth.
Anthrax, dried	growth.

6. Cultures between mattresses:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	growth.

B. *Moist cultures.*

1. Cultures free in chamber:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	growth.

2. Cultures buried in hair pillow:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	growth.

3. Cultures buried in feather pillow:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	growth.

4. Cultures in rolled blanket:

Typhoid, moist	growth.
Diphtheria, moist	no growth.
Anthrax, moist	growth.

5. Cultures buried in cotton mattress:

Typhoid, moist	no growth.
Diphtheria, moist	growth.
Anthrax, moist	growth.

6. Cultures between mattresses:

Typhoid, moist	no growth.
Diphtheria, moist	growth.
Anthrax, moist	growth.

SERIES II.

Temperature of chamber, 80° C.; time, one hour; vacuum, 15 inches.

A. *Dried cultures.*

1. Cultures free in chamber:

   Typhoid, dried.......no growth.
   Diphtheria, dried.......growth.
   Anthrax, dried.......growth.

2. Under the succeeding conditions, as outlined in Series I:

   Typhoid and diphtheria.......were destroyed.
   Anthrax.......grew in each instance.

B. *Moist cultures.*

Under all conditions typhoid and diphtheria were killed; anthrax grew.

SERIES III.

Temperature of chamber, 80° C.; time, one hour; vacuum, 15 inches; 500 c. c. water put in formaldehyd generator, which was operated in the same manner as for formalin:

A. *Dried cultures.*

1. Cultures free in chamber:

   Typhoid, dried.......no growth.
   Diphtheria, dried.......no growth.
   Anthrax, dried.......no growth.

2. Cultures buried in hair pillow:

   Typhoid, dried.......no growth.
   Diphtheria, dried.......no growth.
   Anthrax, dried.......growth.

3. Cultures buried in feather pillow:

   Typhoid, dried.......no growth.
   Diphtheria, dried.......no growth.
   Anthrax, dried.......no growth.

4. Cultures in rolled blankets:

   Typhoid, dried.......no growth.
   Diphtheria, dried.......no growth.
   Anthrax, dried.......growth.

5. Cultures buried in cotton mattress:

   Typhoid, dried.......no growth.
   Diphtheria, dried.......no growth.
   Anthrax, dried.......no growth.

6. Cultures between mattresses:

   Typhoid, dried.......no growth.
   Diphtheria, dried.......no growth.
   Anthrax, dried.......no growth.

B. *Moist cultures.*

1. Cultures free in chamber:

   Typhoid, moist.......no growth.
   Diphtheria, moist.......no growth.
   Anthrax, moist.......no growth.

2. Cultures buried in hair pillow:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	no growth.

3. Cultures buried in feather pillow:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	no growth.

4. Cultures in rolled blanket:

Typhoid, moist	growth.
Diphtheria, moist	no growth.
Anthrax, moist	growth.

5. Cultures buried in cotton mattress:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	no growth.

6. Cultures between mattresses:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	no growth.

As was to be expected, typhoid and diphtheria were killed under most conditions, but the degree of heat was not sufficient to destroy the more resistant anthrax spores. The feather pillow, the tightly rolled blanket, and the cotton mattress were not always penetrated. In the third series the killing of the anthrax in several instances can only be accounted for on the theory that formaldehyd reached it from some source.

Series IV and V show the effect of formaldehyd in considerable quantity at room temperature, about 30° C. It did not penetrate the ten thicknesses of cheese cloth, the only protection around the cultures free in the chamber, in sufficient quantity to kill anthrax, and it also failed to reach the typhoid and diphtheria, save under the first condition. The repetition of this set of experiments with identical results proves that when the exposure is limited to one hour, formaldehyd, even in large percentage, at room temperature is practically inert as a disinfectant.

I am aware that this conclusion was not reached in a previous article (*a*) upon the same subject, but a comparison of the conditions under which the experiments were performed may explain the apparently contradictory results.

SERIES IV.

Quantity of formalin, 500 c. c.; time, one hour; vacuum, 15 inches.

A. *Dried cultures.*

1. Cultures free in chamber:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	growth.

2. Cultures buried in hair pillow:

Typhoid, dried	growth.
Diphtheria, dried	growth.
Anthrax, dried	growth.

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a Sprague, The Medical News, December 11, 1897.

3. Cultures buried in feather pillow:

Typhoid, dried	growth.
Diphtheria, dried	growth.
Anthrax, dried	growth.

4. Cultures in rolled blanket:

Typhoid, dried	growth.
Diphtheria, dried	growth.
Anthrax, dried	growth.

5. Cultures buried in cotton mattress:

Typhoid, dried	growth.
Diphtheria, dried	growth.
Anthrax, dried	growth.

6. Cultures between mattresses:

Typhoid, dried	growth.
Diphtheria, dried	growth.
Anthrax, dried	growth.

B. *Moist cultures.*

The results with moist cultures need not be tabulated, inasmuch as under the above conditions they were identical with the dried cultures; that is, the only organisms killed were typhoid and diphtheria, free in the chamber.

SERIES V.

This was a repetition of Series IV, with identically the same results.

The effect of the combination of heat, 80° C., with formaldehyd is shown in the following series: One, with an exposure of one hour; the other, with an exposure of thirty minutes. The results in each instance were practically the same.

SERIES VI.

Quantity of formalin, 500 c. c.; temperature of chamber, 80° C.; time, one hour; vacuum, 15 inches.

A. *Dried cultures.*

1. Cultures free in chamber:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	no growth.

2. Cultures buried in hair pillow:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	no growth.

3. Cultures buried in feather pillow:

Typhoid, dried	growth.
Diphtheria, dried	no growth.
Anthrax, dried	growth.

4. Cultures in rolled blanket:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	growth.

5. Cultures buried in cotton mattress:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	no growth.

6. Cultures between mattresses:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	growth.

B. *Moist cultures.*

1. Cultures free in chamber:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	no growth.

2. Cultures buried in hair pillow:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	no growth.

3. Cultures buried in feather pillow:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	growth.

4. Cultures in rolled blanket:

Typhoid moist	no growth·
Diphtheria, moist	no growth·
Anthrax, moist	growth.

5. Cultures buried in cotton mattress:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	no growth.

6. Cultures between mattresses:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	growth.

SERIES VII.

Quantity of formalin, 500 c. c.; temperature of chamber, 80° C.; time, 30 minutes; vacuum, 15 inches.

A. *Dried cultures.*

1. Cultures free in chamber:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	no growth.

2. Cultures buried in hair pillows:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	growth.

3. Cultures buried in feather pillow:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	no growth.

4. Cultures buried in rolled blankets:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	growth.

5. Cultures buried in cotton mattress:

Typhoid, dried .... growth.
Diphtheria, dried .... no growth.
Anthrax, dried .... growth.

6. Cultures between mattresses:

Typhoid, dried .... no growth.
Diphtheria, dried .... no growth.
Anthrax, dried .... growth.

B. *Moist cultures.*

1. Cultures free in chamber:

Typhoid, moist .... no growth.
Diphtheria, moist .... no growth.
Anthrax, moist .... no growth.

2. Cultures buried in hair pillow:

Typhoid, moist .... no growth.
Diphtheria, moist .... no growth.
Anthrax, moist .... growth.

3. Cultures buried in feather pillow:

Typhoid, moist .... no growth.
Diphtheria, moist .... no growth.
Anthrax, moist .... growth.

4. Cultures in rolled blankets:

Typhoid, moist .... no growth.
Diphtheria, moist .... no growth.
Anthrax, moist .... growth.

5. Cultures buried in cotton mattress:

Typhoid, moist .... no growth.
Diphtheria, moist .... no growth.
Anthrax, moist .... growth.

6. Cultures between mattresses:

Typhoid, moist .... no growth.
Diphtheria, moist .... no growth.
Anthrax, moist .... growth.

The foregoing experiments indicated that the disinfection of bulky articles, such as mattresses and pillows, could not be accomplished without an increase in the quantity of formalin or the degree of heat; but before instituting any change in the methods of procedure, it was decided to attempt the disinfection of lighter articles and those generally recognized as better adapted for treatment with formaldehyd. In Series VIII, the cultures were put in the pocket of a coat and the garment so arranged that the gas must penetrate the cloth to reach the germs. The same was done for the cultures placed in the trousers pocket. The letter was sealed and without perforation thrown into the chamber.

SERIES VIII.

Quantity of formalin, 500 c. c.; temperature of chamber, 80° C.; time, one hour; vacuum, 15 inches.

B. *Dried cultures.*

1. Cultures free in chamber:

Typhoid, dried .... no growth.
Diphtheria, dried .... no growth.
Anthrax, dried .... no growth.

2. Cultures in coat pocket:

Typhoid, dried	growth.
Diphtheria, dried	no growth.
Anthrax, dried	growth.

3. Cultures in trousers pocket:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	no growth.

4. Cultures in letter:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	no growth.

5. Cultures between leaves of book:

Typhoid, dried	no growth.
Diphtheria, dried	no growth.
Anthrax, dried	no growth.

B. *Moist cultures.*

1. Cultures free in chamber:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	no growth.

2. Cultures in coat pocket:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	growth.

3. Cultures in trousers pocket:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	no growth.

4. Cultures in letter:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	no growth.

5. Cultures between leaves of book:

Typhoid, moist	no growth.
Diphtheria, moist	no growth.
Anthrax, moist	growth.

It was now evident that when anthrax was destroyed the other organisms failed to develop and further work with them was abandoned. At a temperature of 80° C., or more, it was thought that before the formaldehyd entered the chamber the slips of crash must be dried, and in the succeeding experiments the slips were saturated with a bouillon culture of spore-bearing anthrax and placed in the chamber without unnecessary delay. None of the quarantinable diseases is caused by a spore-bearing organism so far as we know, and their infectious principles are not classed as *resistant* to the disinfectants in common use, but in these experiments disinfection has not been considered successful unless the spores of anthrax were killed.

Series IX is a duplicate of Series VIII as to results, although a smaller quantity of formalin was used.

SERIES IX.

Quantity of formalin, 360 c. c.; temperature of chamber, 80° C.; time, 30 minutes; vacuum, 15 inches.

Anthrax, moist, free in chamber	no growth.
Anthrax, moist, in coat pocket	growth.
Anthrax, moist, in trousers pocket	no growth.
Anthrax, moist, in letter	no growth.
Anthrax, moist, between leaves of book	no growth.
Anthrax, moist, under blanket	growth.

From the last two series, it was more than ever evident that even to disinfect articles comparatively easily penetrated the quantity of formalin, or degree of heat, or both, must be increased. The next seventeen series indicate that the degree of heat is the more important. This is well illustrated by Series X, XIV, and XVI, in which, with an increase of the temperature of the chamber to 90° C., disinfection was complete, while in Series IV, V, VI, VII, VIII, in which the same quantity of formalin, 500 c. c., was used, but at a lower temperature, anthrax was only rarely destroyed.

SERIES X.

Quantity of formalin, 500 c. c.; temperature of chamber, 90° C.; time, 30 minutes; vacuum, 15 inches.

Anthrax, moist, free in chamber	no growth.
Anthrax, moist, in coat pocket	no growth.
Anthrax, moist, in trousers pocket	no growth.
Anthrax, moist, in letter	no growth.
Anthrax, moist, between leaves of book	no growth.
Anthrax, moist, under blanket	no growth.

When the formaldehyd was turned into the chamber for the above series the temperature was only 80° C., but it quickly rose to 90° C.

Series XIV and XVI confirmed Series X with identical results. In Series XVI were included the following experiments:

Anthrax, moist, buried in hair pillow	no growth.
Anthrax, moist, buried in feather pillow	no growth.
Anthrax, moist, buried in cotton mattress	no growth.
Anthrax, moist, between mattresses	no growth.

SERIES XI.

Quantity of formalin, 750 c. c.; temperature of chamber, 90° C.; time, 30 minutes; vacuum, 15 inches.

Anthrax, moist, free in chamber	no growth.
Anthrax, moist, in coat pocket	no growth.
Anthrax, moist, in trousers pocket	no growth.
Anthrax, moist, in letter	no growth.
Anthrax, moist, between leaves of book	no growth.
Anthrax, moist, under blanket	no growth.

Series XV and Series XVIII confirmed Series XI with identical results. In Series XVIII were included the following experiments:

Anthrax, moist, buried in hair pillow	no growth.
Anthrax, moist, buried in feather pillow	no growth.
Anthrax, moist, buried in cotton mattress	no growth.
Anthrax, moist, between mattresses	no growth.

SERIES XII.

Quantity of formalin, 1,000 c c.; temperature of chamber, 90° C.; time, 30 minutes; vacuum, 15 inches.

Anthrax, moist, free in chamber	no growth.
Anthrax, moist, in coat pocket	no growth.
Anthrax, moist, in trousers pocket	no growth.
Anthrax, moist, in letter	no growth.
Anthrax, moist, between leaves of book	no growth.
Anthrax, moist, under blanket	no growth.

SERIES XIII.

Quantity of formalin, 360 c. c.; temperature of chamber, 90° C.; time, 30 minutes; vacuum, 15 inches.

Anthrax, moist, free in chamber	no growth.
Anthrax, moist, in coat pocket	no growth.
Anthrax, moist, in trousers pocket	no growth.
Anthrax, moist, in letter	no growth.
Anthrax, moist, between leaves of book	no growth.
Anthrax, moist, under blanket	no growth.

SERIES XVII.

Quantity of formalin, 360 c. c.; temperature of chamber, 90° C.; time, 30 minutes; vacuum, 15 inches.

Anthrax, moist, free in chamber	no growth.
Anthrax, moist, in coat pocket	no growth.
Anthrax, moist, in trousers pocket	no growth.
Anthrax, moist, in letter	no growth.
Anthrax, moist, between leaves of book	no growth.
Anthrax, moist, under blanket	no growth.
Anthrax, moist, buried in hair pillow	no growth.
Anthrax, moist, buried in feather pillow	no growth.
Anthrax, moist, buried in cotton mattress	no growth.
Anthrax, moist, between mattresses	no growth.

It will be observed that this series is a duplicate of Series XIII, with four additional experiments.

Series XIX, XX, XXV, XXVI, and XXVII confirmed Series XIII with identical results.

In Series XXV and XXVI disinfection was not secured in the more bulky articles.

Although the results obtained in seven series with 360 c. c. of formalin were satisfactory it was considered desirable to fix upon the minimum efficient quantity. To that end, experiments were made with 100 c. c. and 200 c. c. of the mixture, and finally with 100 c. c. of formalin, to which was added 400 c. c. of water with calcium chloride and glycerin in the same proportion as for 500 c. c. of formalin. This last series seemed to indicate that penetration is greater for a small quantity of formaldehyd if a little moisture is present; the results certainly are better than in Series XXII, in which the quantity of formalin was actually the same. One chief advantage for formaldehyd is that it is efficient in a dry state, and is, therefore, available for disinfection of articles injured by moisture. For that reason the water of the formalin should not be increased in actual work. These three series are a proof, if any is necessary, that the germicidal effects in the preceding series were due to the formaldehyd, the heat acting merely as an intensifier.

SERIES XXII.

Quantity of formalin, 100 c. c.; temperature of chamber, 90° C.; time, 30 minutes; vacuum 15 inches.

Anthrax, moist, free in chamber	no growth.
Anthrax, moist, in coat pocket	growth.
Anthrax, moist, in pants pocket	growth.
Anthrax, moist, in letter	growth.
Anthrax, moist, in book	growth.
Anthrax, moist, under blanket	growth.
Anthrax, moist, in hair pillow	growth.
Anthrax, moist, in feather pillow	growth.
Anthrax, moist, in cotton mattress	growth.
Anthrax, moist, between mattresses	growth.

SERIES XXIII.

Quantity of formalin, 200 c. c.; temperature of chamber, 90° C.; time, 30 minutes; vacuum, 15 inches.

Anthrax, moist, free in chamber	no growth.
Anthrax, moist, in coat pocket	no growth.
Anthrax, moist, in pants pocket	no growth.
Anthrax, moist, in letter	no growth.
Anthrax, moist, in book	no growth.
Anthrax, moist, under blanket	growth.
Anthrax, moist, in hair pillow	growth.
Anthrax, moist, in feather pillow	growth.
Anthrax, moist, in cotton mattress	growth.
Anthrax, moist, between mattresses	no growth.

SERIES XXIV.

Quantity of formalin, 100 c. c., to which was added 400 c. c. of water, calcium chloride 100 gms., and glycerin 50 c. c.; temperature of chamber, 90° C.; time, 30 minutes; vacuum, 15 inches.

Anthrax, moist, free in chamber	no growth.
Anthrax, moist, in coat pocket	no growth.
Anthrax, moist, in pants pocket	no growth.
Anthrax, moist, in letter	no growth.
Anthrax, moist, in book	no growth.
Anthrax, moist, under blanket	no growth.
Anthrax, moist, in hair pillow	no growth.
Anthrax, moist, in feather pillow	no growth.
Anthrax, moist, in cotton mattress	no growth.
Anthrax, moist, between mattresses	no growth.

Series X confirmed by Series XIV and XVI, in all of which 500 c. c. of formalin was used, with a temperature of 90° C. in the chamber; Series XI confirmed by Series XV and XVIII, in which 750 c. c. of formalin was used; and Series XII with 1,000 c. c. of formalin—seven separate experiments with identical results—prove conclusively the efficiency of formaldehyd as disinfectant when combined with heat. In another set of seven experiments, Series XIII, XVII, XIX, XX, XXV, XXVI, XXVII, with only 360 c. c. of formalin and 90° C. of heat, it will be observed that the results were equally as good as with more of the solution except in Series XXV and XXVI, in which without any apparent cause there was failure to secure disinfection of the bulkier articles.

As previously mentioned, in these experiments no estimation of the percentage of gas in the chamber has been attempted. To make them of practical value a ratio may be established between the number of cubic centimeters of solution used and the number of liters capacity of the chamber.

This cylinder had a capacity of 1,680 liters. The ratio of 1,000: 1,680 is rather more than 1:2; that of 750:1,680 is something less than

1:2; that of 500:1,680 is about 1:3; while that of 360:1,680 is a trifle more than 1:5. Once the capacity of the chamber in which the work is to be performed is known the proper quantity of the mixture required is readily determined.

The writer would be distinctly understood as not recommending formaldehyd, even when combined with a high degree of heat, as a disinfecting agent upon which reliance can always be placed for the treatment of articles requiring much penetration, especially when the exposure is limited to one-half hour. A review of the experiments will show that in twelve series in which the quantity of formalin mixture varied from 360 c. c. to 1,000 c. c., or taking the ratio given, from 1:5 to 1:2 mattress and pillows were sterilized; but in two series in which the proportion of the mixture was as 1:5 the mattresses and pillows were not penetrated. A critical examination of nearly all the published experiments with this agent will reveal instances in which organisms that there was every reason to expect would be killed have survived, and vice versa. It is that occasional unaccountable uncertainty of action that calls forth the warning not to attempt disinfection with formaldehyd in a case in which there is any doubt as to the result.

Care must be taken to arrange the various articles in such a manner that a free circulation is allowed around and among them. If the contents of a trunk were thrown into the chamber in a heap it would not be penetrated. The articles which can be treated successfully will be found in practice to be wearing apparel, books, letters, and such other things as do not require deep penetration. Whenever possible they should be suspended on hooks or lines or so spread that the largest possible surface is exposed. Leather goods, trunks, suit cases, etc., may be subjected to 90° C., dry heat, without injury. The elasticity of rubber is apparently not diminished.

OUTLINE OF METHOD.

1. Heat jacket with steam so that temperature of chamber is 90° C.
2. Pour into formalin generator one fourth as many c. c. of formalin mixture as there are liters capacity in chamber, e.g. 625 c. c. for a chamber of 2,500 liters capacity.
3. Obtain a vacuum of 15 inches or one-half an atmosphere.
4. When pressure in generator reaches 40 to 60 pounds open the valve just enough to allow a gradual reduction of pressure by the passage of formaldehyd into the chamber. If this valve is opened too wide the fluid may be driven into the chamber and its contents injured.
5. When it is found that all the gas is driven off close the valve to the chamber.
6. Maintain temperature of chamber at 90° C., or even higher, by allowing steam to course through jacket.
7. At end of thirty minutes the vacuum may be broken and the mixture of air and formaldehyd exhausted.
8. With a vacuum of 10–15 pounds the ammonia generator may now be operated in the same manner, using one-half as much ammonia water as of the formalin mixture.
9. After the ammonia gas has entered the chamber the vacuum may be at once broken and the chamber opened.
10. Each time, after the formalin generator is operated, it should be thoroughly cleansed with water. If the sirupy residue is not removed it soon fouls the apparatus and clogs the outlet.

Respectfully, yours,
E. K. SPRAGUE,
Acting Director.

The SURGEON-GENERAL, *U. S. Marine-Hospital Service.*